IV-2 ONE-DIMENSIONAL FLOW

2. Examples of Flow

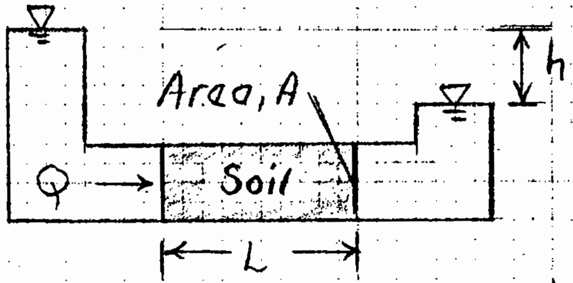
3. Computation of Effectives Stresses With Seepage

CCL 10/20/83 10/84 10/87 10/88 10/96 10/98 10/00 1.361-1.366

Part IV - 2 ONE DIMENSIONAL FLOW (Chap. 17)

1. FUNDAMENTALS OF FLOW

1.1 <u>Darcy's Law</u> (Laminar flow)



- Flow Q (ℓ^3/t)

$$= k\frac{h}{L}A = \underline{\underline{kiA = Q}}$$

where

k = coef. of permeability $(\ell/t)^*$

h = change in <u>total</u> head (loss thru soil) (ℓ)

i = hydraulic gradient = $\frac{h}{L}$ (dimensionless)

* Now called <u>hydraulic conductivity</u>

Note: Turbulent flow if high i + coarse grained

1.2 <u>Heads</u> $\left(= \frac{\text{energy}}{\text{"unit weight"}}\right)$

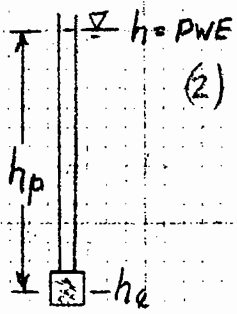
↑ force/unit volume

(1) General

$\frac{1}{2}\frac{V^2}{g}$ } Kinetic Energy

$$\underbrace{\text{Total head } h}_{\text{Causes Flow}} = \underbrace{h_{\text{physico-chemical}} + h_{\text{velocity}}}_{\text{Can neglect}} + \underbrace{h_{\text{elevation}} + h_{\text{pressure}}}_{\text{Potential Energy}}$$

↑ Except 1st for contaminant transport



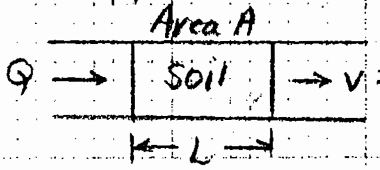
(2) Used for flow thru soils

$$\left\{\begin{array}{l} h = h_e \quad \text{(elevation head wrt some } \underline{\text{arbitrary}} \text{ datum)} \\ \quad + h_p \quad \text{(pressure head} = u/\gamma_w = \text{height of } H_2O \text{ in piezometer)} \end{array}\right.$$

Piezometric water elevation (PWE) = TOTAL HEAD = elevation of top of water in piezometer

1.3 <u>Flow Velocities</u>

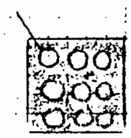
(1) Approach velocity (v)



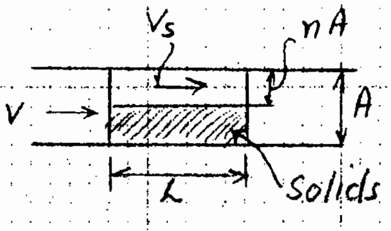
$$\rightarrow v = \frac{Q}{A} = \boxed{ki = v}$$

$$n = \frac{V_v}{V} = \frac{A_v}{A}$$

ΣO = Area Voids = n Area



(2) Seepage velocity (V_s)



- If treat soil as straight <u>capillary</u> tubes

Volume Voids = n Volume soil

$$Q = vA = V_s A_v = V_s nA \qquad \left(\frac{L \times A_v}{L \times A} = \frac{V_v}{V} = n\right)$$

$$\therefore V_s = \frac{v}{n} \quad \text{and} \quad t = \frac{L}{V_s} = \frac{Ln}{v}$$

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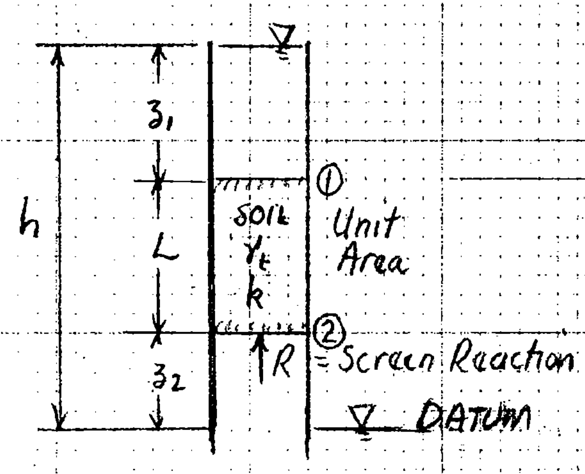
Part IV-2 1-D FLOW

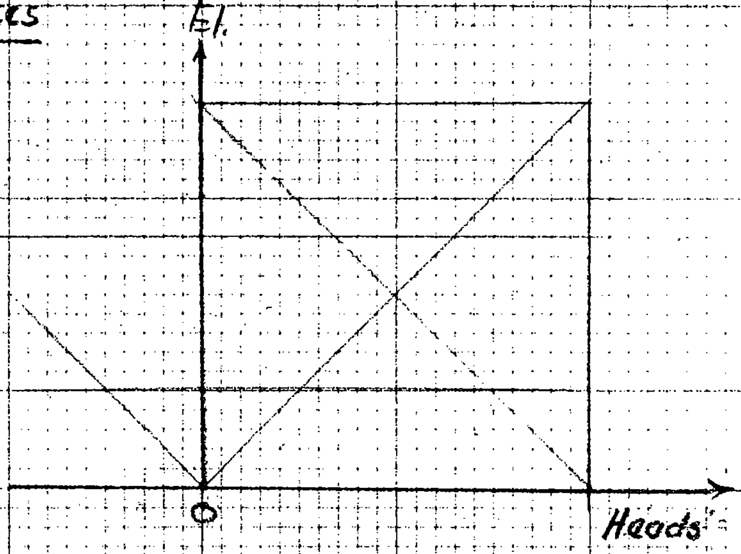
3. COMPUTATION OF EFFECTIVE STRESSES WITH SEEPAGE

3.1 Two Approaches (For both, always get $h = h_e + h_p$ for "system")

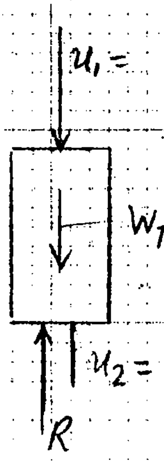
- "External Forces" = Total Weights + Boundary (Water) Forces
- "Internal Forces" = Buoyant Weights + Seepage Forces

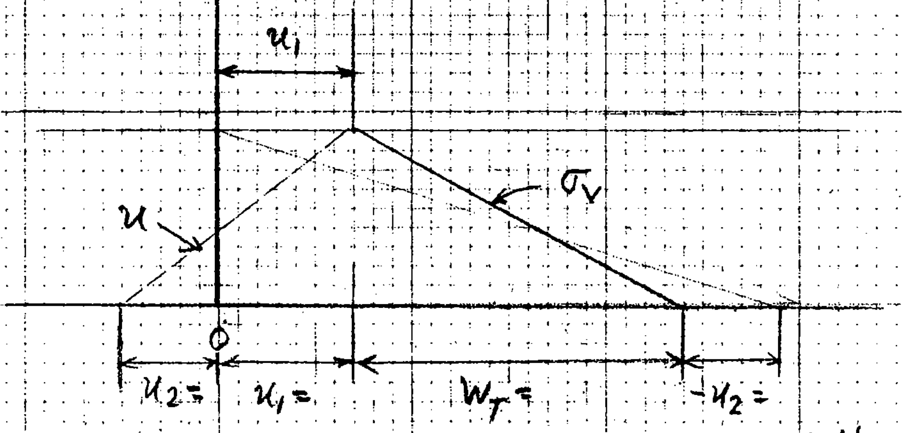
3.2 Approach: External Forces





Isolate Soil (Unit area)





Steps: (Note: assumes $\sigma'_v = 0$ at one of the boundaries)

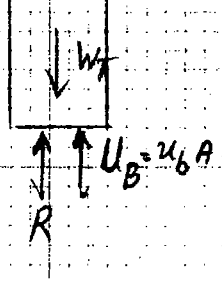
(1) Get h @ T & B

(2) Get $h_p \rightarrow U_T$ & U_B

(3) Compute $W_T = \gamma_t L A$

(4) $R = \sigma'_v A = U_T + W_T - U_B$

NOTE: Within soil, $\sigma'_v = \sigma_v - u$;
start with boundary
having known $\sigma'_v = \sigma_v - u$

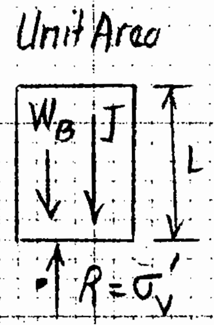


NOTE: R can act ↑ or ↓ (also can have R forces acting on both boundaries)

Part IV-2 1-D FLOW

3.3 Approach: Internal Forces

- Reaction = force due to buoyant weight of soil (W_B = magnitude w/o flow = $\gamma_b L$) + drag forces due to seepage ($J = jL$)
- Define $j = \frac{\text{seepage force}}{\text{unit volume}} = i\gamma_w = \frac{h}{L}\gamma_w$ which acts in direction of flow



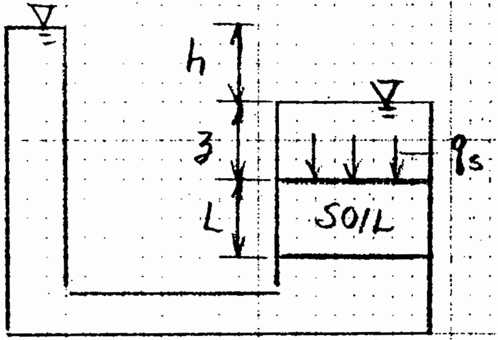
$$R = W_B + J = \gamma_b L + \underbrace{\frac{h}{L}\gamma_w L}_{\to h\gamma_w}$$

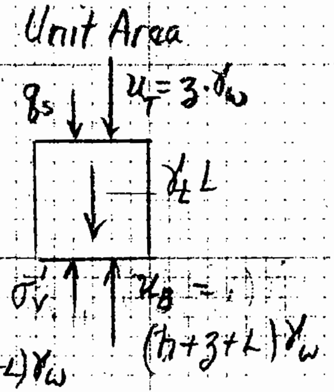
- Comparison of 2 approaches

$R =$

NOTE: If $\gamma_f \neq \gamma_w$, then $\gamma_b = \gamma_t - \gamma_f$ and $j = i\gamma_f$

3.4 Example With Upward Flow





(1) External Forces

$$R = \sigma_v' = q_s + z\gamma_w + \gamma_t L - (h+z+L)\gamma_w$$
$$= q_s + L(\gamma_t - \gamma_w) - h\gamma_w$$

(2) Internal Forces: $\sigma_v' = q_s + \gamma_b L - J \left\{ = jL = i\gamma_w L = \frac{h}{L}\gamma_w L = h\gamma_w \right\}$

(3) For $R = \sigma_v' = 0$ at bottom

$$h_{cr} = \frac{q_s + \gamma_b L}{\gamma_w}$$

(4) For $q_s = 0$ ($\therefore \sigma_v' = 0$ throughout)

$$h_{cr} = \frac{\gamma_b L}{\gamma_w}$$ or critical gradient $i_{cr} = \frac{\gamma_b}{\gamma_w}$

3.5 "Quick" Condition (Quick Sand when $\sigma_v' = 0$ cohesionless soil)

- Acts as heavy fluid since strength → 0 when $\sigma' \to 0$
- $i_{cr} = 1.04 \pm 0.08$ for sandy materials ($\gamma_b = 65 \pm 5$ pcf) and independent of soil thickness
- Fine sands & cohesionless silts most susceptible as require less flow
- Reality vs movies